(8) **Johnson, W. D.** The High Plains and their utilization. Ann. rept., U. S. Geol. Surv., 1901, **21** iv:609-768.
(9) **Henry, A. J.** Rainfall and snowfall of the United States, with annual seasonal, monthly and other charts. Washington, 1897. 58 p. 3 pl. 11 charts, 11 tables. 4°. (U. S. Weather Bur. bull. D.) (W. B. 136).
(10) **Lee, C. H.** Precipitation and altitude in the Sierra. MONTHLY WEATHER REVIEW, Washington, 1911, **39**:1092-1099.

B. General references.

There are many discussions of rainfall of the United States as a whole, as well as of individual sections and States. The following list, arranged alphabetically, contains the more important general recent publications dealing with the mean annual precipitation which have not been listed under "A."

The titles under "B" do not include discussions or maps of the rainfall of special districts.

Atlas of Meteorology (Bartholomew's Physical Atlas, III). Edinburgh, 1899. Plate No. 21; text, p. 20. f°.
Bibliography of Meteorology. A classed catalogue of the printed literature of Meteorology from the origin of printing to the close of 1881; with a supplement to the close of 1889, and an author index. Prepared under the direction of Brig. Gen. A. W. Greely, Chief Signal Officer, U.S.A. Edited by Oliver L. Fassig. Washington, 1891. 4°. Part II.—Moisture (distribution of rainfall in the United States, p. 237-242).
Bigelow, Frank H. The daily normal temperature and the daily normal precipitation of the United States. Washington, 1908. 186 p. 4°. (U. S. Weather Bur. Bull. R.) (W. B. 395).
Gannett, Henry. Rainfall maps of the United States. These have been published as follows: Ann. rept., U. S. Geol. Surv., 1894, **14, ii**, Pl. VI; MONTHLY WEATHER REVIEW, 1902, **30**, Pl. 40; U. S. Geol. Surv. Water Supply Paper **234**, 1909, Pl. I; *ibid.* No. **301**, 1912, Pl. I; also as Pl. I in each number from **302** to **312**, 1912-1914.
Harrington, M. W. Rainfall and snow of the United States, compiled to the end of 1891, with annual, seasonal, monthly, and other charts. Atlas and text, Washington, 1894. (U. S. Weather Bur., bull. C) Short bibliography, pp. 8-9.
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Pages 47-59 on precipitation, with chart of normal annual precipitation, and rainfall data for over 600 regular and cooperative stations.

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Jefferson, Mark. Aridity and humidity maps of the United States. Bull., Amer. geogr. soc., 1916, —: 203-208.
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The reduction of records of rain gauges. MONTHLY WEATHER REVIEW, Washington, 1901, **29**:499-500. (Remarks on the foregoing, by A. J. Henry, *ibid.*, p. 500-501.)
Reed, William Gardner. Cyclonic distribution of rainfall in the United States. MONTHLY WEATHER REVIEW, Washington, 1911, **39**: 1609-1615.
U. S. Weather Bureau. Summaries of climatological data. Washington, 1914, etc., var. pag. 11½ x 9½ in. (Bulletin W.) (W. B. 476.)

Contains monthly and annual mean rainfalls, year by year, since the beginning of the observations.

551.55 (747)

SEA BREEZE ON EASTERN LONG ISLAND.

By ERNEST S. CLOWES.

[Dated: Bridgehampton, Long Island, May 4, 1917.]

While quite a little study has been given to the sea breeze in the Temperate Zone I have not yet found any series of observations recording the temperature values at varying distances from the sea coast at any particular time during the sea breeze's progress inland. Records have been kept of its actual velocity and of the velocity of penetration and of its depth, but the temperature factor has been largely covered with the banal generalization that the effect of the breeze is to lower the temperature considerably.

For several years I have kept a Draper recording thermometer during the summer months at the locality known as Mecox, about 2 miles south of the village of Bridgehampton, Long Island, N. Y., and about 100 miles east of New York City. The thermometer has been well sheltered in a covered porch exposed to the southwest. It is distant about a quarter mile from the ocean by the shortest line, but about one-half to three-quarters in the prevailing direction of the sea breeze, that is southwest. The coast at this point and for miles in both directions runs about ENE and WSW. The country is generally level, open farming land for about 4 miles back from the sea, where after already having risen about 60 feet above tide the land breaks into a row of tree-covered hills about 200 to 280 feet in height. The last three summers on Long Island were generally so cool and damp that sea-breeze days were rather rare, but the month of July, 1912, was a sea-breeze month par excellence and most of the observations here recorded were made at that time.

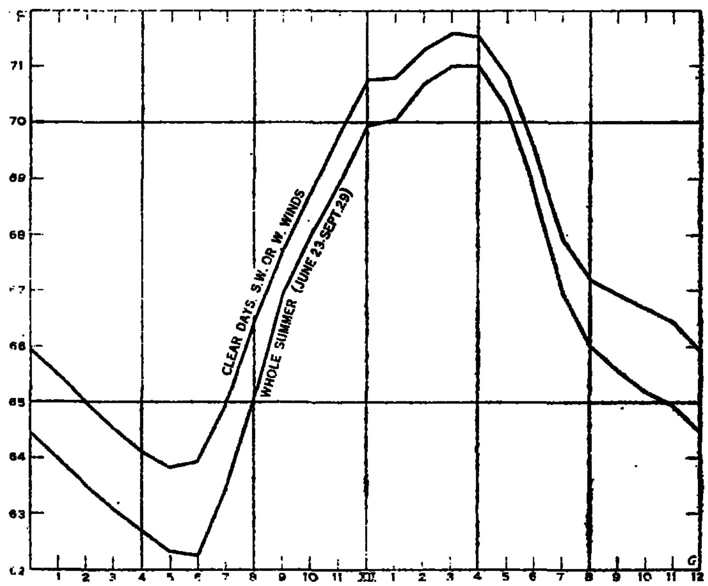

FIG. 1.—Daily temperature curve at "Hopewell," Bridgehampton, L. I. Upper curve based on 70 clear days with southwest or west winds. Lower curve average of the summer, June 23 to Sept. 29, inclusive.

The following series of daily temperature curves shows strikingly the effect of the sea breeze on temperature.[1] Figure 1 shows the average daily curve at Mecox from June 23 to July 21, 1912, a period of almost uninterruptedly fine, warm weather. The double maximum effect is clearly shown. Another interesting feature is the flattening out of the curve between 8 and 9 p. m. This is characteristic of sea-breeze weather, some days even showing a higher temperature at 9 than at 8 p. m. This is due to the cessation of the sea breeze about sun-down and the turn of the wind, usually very light, toward the land. This is not a true land breeze, for the air over the land is warmer than over the sea, but rather a return of the wind to its normal direction.

Figure 2 gives curves which show the average hourly temperatures at certain Weather Bureau stations for the same period June 23—July 21, 1912 in comparison with that at Mecox. This comparison presents interesting features. Besides Mecox, the only other curve that presents a double maximum is that for Atlantic City which gives nearly a triple maximum. This is also a

[1] The author would here acknowledge his obligations to the U. S. Weather Bureau officials at the local offices in Nantucket, Atlantic City, and New York City, all of whom have furnished data used in this study. He is particularly indebted to those at Nantucket and Atlantic City for the large number of individual hourly temperatures furnished.

seacoast station, but the coast there runs about NNE–SSW. so that a sea breeze has to contend more against the prevailing westerly wind, and its effects are therefore more fitful and the lowering of the temperature not as great. New York presents a typical continental curve with a maximum at 2 p. m. The slight dent between 3 and 4 p. m. may be due to a slight sea-breeze effect or to the fact that summer thunderstorms occur about that time. Nantucket is a typical marine station with the maximum near noon. The fact that a marine station like Nantucket has a higher maximum than Mecox, which if not on the continent is nearer to it and part of a much larger land area, may be explained by the fact that the Nantucket station is on the north side of the Island so that the prevailing southwest breeze has to come some distance overland. The Mecox station, as stated, is not over three-quarters of a mile down wind from the shore. Their minima are nearly identical. Atlantic City shows a higher temperature from 7 to 8:30 a. m. than New York although the average noonday temperature at New York is 5½ degrees warmer. This is probably due to the relative elevation of the instruments; those at Atlantic City being nearer the ground warm up quicker than those at New York at 400 feet elevation.

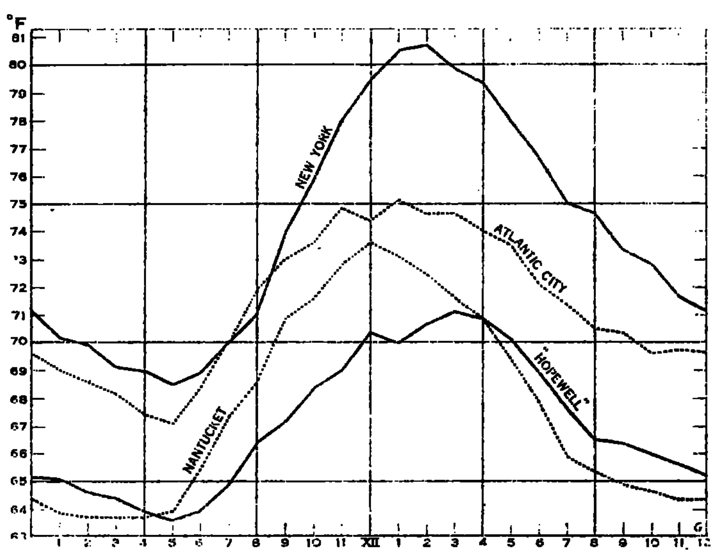

FIG. 2.—Daily temperature curve at "Hopewell," Bridgehampton, L. I., for the period June 23 to July 21, 1912, compared with the corresponding curves for the same period at the Weather Bureau offices in New York, Atlantic City, N. J., and Nantucket, Mass.

While I found only one recorded observation in support, I believe that the sea breeze is felt some little distance aloft before it is on the surface (Am. met. journ., 9: 134). My own reason is that from my point of observation the sound of the sea always precedes the onset of the breeze by several minutes. Normally on sea-breeze days there is but little surf and with a land breeze the sound is inaudible one quarter mile inland. The first symptom of the coming sea breeze is the sound of the surf in the direction from which the breeze will probably make its appearance; the sound waves traverse the already landward moving air at some little altitude, the value of which it would be interesting to determine. The breeze then approaches the surface, or rather its surface contact—which at its inception is a mile or two seaward—gradually advances inland, the rapidity of its advance and its own proper velocity depending on the temperature gradient inland. From my own observation I would say that if the gradient is steep the velocity of the breeze is high but its velocity of penetration [advance] low, if the gradient is more gradual the breeze velocity is less but its penetration [advance] more rapid; in other words, its upward component seems to be proportional to the temperature gradient. That is merely a theory, derived not from any accurate temperature measurements at varying distances inland but as the result of a good many years observation of general conditions. I know that generally speaking the hotter the day the surer we are, at Mecox, of a sea breeze; but if the day be very hot the breeze may not reach Bridgehampton, 2½ miles inland, before 2 or 3 p. m., while the shore enjoys a good breeze all day. I have seen, in mid-afternoon, a difference equalling 93° − 76° = 17 degrees between Bridgehampton and the ocean, but that is a very exceptional case for that time of day. In ordinary sea breeze weather the difference at noon is usually about 10°.

An interesting feature seems to be that this temperature gradient is not a constant feature of the summer climate; there are many days when it does not amount to more than 3 or 4 degrees. That is, there are days, and always during hot waves, when the interior becomes greatly overheated and the sea breeze ensues; but on the shore these days are indistinguishable from ordinary summer weather. We do not know it is hot until we go inland, and the farther we go the hotter it gets. I believe that at such times temperature observations taken about 9 a. m. at varying altitudes, both at the coast line and inland, would show a temperature inversion, specially on the coast. In hot-wave weather the atmosphere as a whole over the affected area is superheated, but along the coast the cooling effect of the sea causes a lower temperature below than aloft. This is borne out by observations taken on the U. S. Coast Guard Cutter *Seneca* (MONTHLY WEATHER REVIEW Supplement 3, 1916), which show a temperature inversion up to 200 meters in both spring and early summer over nearly all waters except the Gulf Stream, this inversion if anything being greater in summer. The following conditions also confirm this: On July 3, 1911, the maximum temperature at Mecox was about 77°; at New York it was 98°; in Boston 103°, and between 90° and 100° at all interior points in the Northeastern States. This is an extreme instance, but it is specially noteworthy that Boston—about 140 miles northeast of Long Island and down the wind, which was quite fresh along the coast—showed a maximum 20 degrees or more above that of coastal points, although Boston is only about 50 miles from the shores of Narragansett Bay. On that day the whole atmosphere was heated and hot-wave weather prevailed, except at low altitudes over the sea and the adjacent coasts. A determination of the height of the sea breeze on such a day and also of the vertical temperature gradient, would be of great interest.

It seems probable that a thorough study of the sea breeze right here at our doors, specially of the temperature factor, might throw a little more light on the whole problem of convectional circulation over continental areas. The fundamental conditions here exist in miniature and while there may be too many local factors to make such a study of great value, we may remember that many a big generalization has been hatched in a test tube.